VALIDATION OF THE PRESENCE OF AN ELECTROMAGNETIC TRANSPONDER IN THE FIELD OF A READER

Background Of The Invention

1. Field of the Invention

The present invention relates to systems using electromagnetic transponders, that is, transceivers (generally mobile) capable of being interrogated in a contactless and wireless manner by a unit (generally fixed), called a read and/or write terminal. Generally, transponders extract the power supply required by the electronic circuits included therein from the high frequency field radiated by an antenna of the read and write terminal.

2. Discussion of the Related Art

Fig. 1 very schematically shows a conventional example of a data exchange system of the type to which the present invention relates between a read/write terminal 1 and a transponder 10.

Generally, terminal 1 is essentially formed of a series oscillating circuit formed of an inductance L1 in series with a capacitor C1 and a resistor R1, between an output terminal 2 of an amplifier or antenna coupler 3 and a terminal 4 at a reference potential (generally, the ground). Amplifier 3 receives a high-frequency transmission signal E, provided by a modulator 5 (MOD1), which receives a reference frequency (signal OSC), for example, from a quartz oscillator (not shown). Modulator 5 receives, if necessary, a data signal Tx to be transmitted and, in the absence of a data transmission from the terminal, provides the high-frequency carrier (for example, at 13.56 MHz) adapted to remotely supply a transponder. In receive mode, terminal 1 uses a demodulator 6 (DEMOD1), which is used to detect a load variation generated by transponder 10 on the high-frequency signal. Demodulator 6 takes, for example, the voltage across terminals 7 and 4 of capacitor C1, and provides a signal Rx of data received after demodulation.

Other circuits, not shown, generally complete a terminal 1. Among these circuits, a circuit for controlling and exploiting the received data based, most often, on a microprocessor for processing the control signals and the data, may be included, among others. These circuits generally communicate with different input/output circuits (keyboard, screen, means of transmission to a provider, etc.) and/or processing circuits, not shown. The circuits of the

read/write terminal draw the power required by their operation from a supply circuit (not shown) connected, for example, to the electric supply system or to batteries.

A transponder 10, intended for cooperating with a terminal 1, essentially includes a parallel oscillating circuit formed of an inductance L2, in parallel with a capacitor C2 between two input terminals 11, 12 of a control and processing circuit 13. Terminals 11, 12 are in practice connected to the input of a rectifying means (not shown), outputs of which form D.C. supply terminals of the circuits internal to the transponder. These circuits generally include, essentially, a microprocessor 14 (P) capable of communicating with other elements (for example, a memory) through connections 15. Transponder 10 further includes a demodulator 16 (DEMOD2) of the signals received from terminal 1, which provides a signal Rx' to circuit 14, and a modulator 17 (MOD2) for transmitting to the terminal data Tx' that it receives from circuit 14.

The oscillating circuits of the terminal and of the transponder are generally tuned on a same frequency corresponding to the frequency of an excitation signal of the terminal's oscillating circuit. This high-frequency signal (for example, at 13.56 MHz) is not only used as a transmission carrier but also as a remote supply carrier for the transponder(s) located in the terminal's field. When a transponder 10 is located in the field of a terminal 1, a high-frequency voltage is generated across terminals 11 and 12 of its resonant circuit. This voltage, after being rectified and possibly clipped, is intended for providing the supply voltage of electronic circuits 13 of the transponder. For clarity, the rectifying, clipping, and supply means have not been shown in Fig. 1. It should be noted that, generally, the demodulation (block 16) is performed upstream of the clipping means to preserve the amplitude modulation of the data on the high-frequency carrier transmitted by the terminal. This amplitude modulation is performed according to different coding techniques to transmit data and/or control signals to the transponders. In return, data transmission Tx' from the transponder to a terminal is generally performed by modulating the load formed by resonant circuit L2, C2. This is why modulator 17 has been shown in parallel with this resonant circuit. The load variation is performed at the rate of a so-called back-modulation sub-carrier, of a frequency (for example, 847.5 kHz) smaller than that of the carrier.

The load variation coming from a transponder can then be detected by the terminal in the form of an amplitude variation or of a phase variation by means, for example, of a

measurement of the voltage across capacitor C1 or of the current in the oscillating circuit by means of demodulator 6.

A problem that is posed in conventional electromagnetic transponder systems is that a transponder remotely supplied by a terminal and transmitting data to said terminal may be undetected by the terminal, that is, the terminal's demodulator cannot manage to detect the presence of a data modulation. This phenomenon is generally called a "demodulation gap". For a given system, this corresponds to a relative position of a terminal and of a transponder to which the terminal's demodulator is "blind".

It should be noted that this notion of a demodulation gap is different from what is called a "remote supply gap" where the transponder cannot manage to be supplied by the high-frequency signal, even though it is in the terminal's electromagnetic field. Indeed, there exists a relative position between a transponder and a terminal at which the magnetic coupling between oscillating circuits is such that the transponder is not supplied, that is, the voltage recovered across terminals 11 and 12 of its oscillating circuit is too small for it to operate. In a demodulation gap, the transponder is properly supplied. It generally properly detects the data transmitted by the terminal in amplitude modulation. It properly transmits data to the terminal in back-modulation, by variation of the load of its oscillating circuit. However, the terminal's demodulator does not detect this back-modulation.

As a result of this demodulation gap problem, a terminal cannot detect a transponder present in its field since this detection conventionally uses the result of the data demodulator on the terminal side. In particular, when it is in a stand-by state, waiting for a transmission, the terminal periodically transmits interrogation requests by modulating the amplitude of the remote supply carrier. The terminal then monitors the output of its demodulator which will indicate thereto the presence of a transponder. Indeed, where a transponder is "woken up" by its entering the field of a terminal, it demodulates the interrogation message periodically transmitted by this terminal and answers it to have itself identified.

An additional disadvantage is that, since the transponder has received data from the terminal, it believes that it is identified by the terminal, which is not true. The only current techniques to isolate this phenomenon are to multiply the information exchanges to validate the transmission, which is costly in terms of transmission duration.

Different transponder systems of the type to which the present invention applies are described, for example, in US patents no. 4,963,887 and 5,550,536, as well as in European

patent applications no. 0,722,094 and 0,857,981, all of which are incorporated herein by reference.

In a read/write terminal provided with an amplitude demodulator, the output voltage of a demodulator annuls, that is, there is a demodulation gap, in two frequency configurations of the carrier (13.56 MHz) which, for a given coupling coefficient between the oscillating circuits of the terminal and of the involved transponder, surround the self-resonant frequency of oscillating circuit L2-C2 of the transponder. Ideally, the median frequency corresponds to the perfect tuning of the terminal and of the transponder on the remote supply carrier frequency, where the amplitude available for the demodulation is maximum.

It is generally desired to have both the oscillating circuits of the terminal and of the transponder tuned on the remote supply carrier frequency, to maximize the remote supply power received by the transponder. However, the manufacturing tolerances of the capacitors used for the oscillating circuits, especially for capacitor C2 of the transponder, which is generally integrated, generally are on the order of 10%. As a result of the extent of these manufacturing tolerances, perfect tuning is practically not respected and it cannot be guaranteed that a transponder entering the field of a terminal will not be, in a given coupling position, in a demodulation gap.

Further, the position of demodulation gaps in the amplitude demodulator response varies according to the mutual inductance between the oscillating circuits. Now, this mutual inductance depends on the distance separating antennas L1 and L2 of the terminal and of the transponder, and thus on the relative position of the transponder with respect to the terminal upon transmission.

In a read/write terminal provided with a phase demodulator, the output voltage of the demodulator annuls, that is, there is a demodulation gap, in a frequency configuration which, for a given coupling coefficient between the oscillating circuits of the terminal and of the involved transponder, corresponds to the perfect tuning of the terminal and of the transponder on the remote supply carrier frequency. On the transponder side, this frequency then is the self-resonant frequency of oscillating circuit L2-C2 of the transponder.

It has already been provided to permanently detune the oscillating circuits of the terminal and of the transponder so that the two circuits are not both tuned on the remote supply carrier frequency. However, a disadvantage that results therefrom is that this adversely affects the transponder remote supply, and thus the system range.

Further, the extent of capacitor manufacturing tolerances leads to having to substantially shift from the carrier frequency if it is desired to decrease risks of demodulation gaps.

Thus, a significant disadvantage of conventional phase demodulation systems is that a compromise must be made between the remote supply and the capacity of phase demodulation by the terminal. Further, this compromise is difficult to achieve, since the position of the gap in the phase demodulator response varies according to the mutual inductance between these oscillating circuits.

The combined problems of the existence of demodulation gaps and of the variation of the position of these demodulation gaps with respect to the distance between the inductances, associated with the manufacturing tolerances of the components, make conventional systems rather unreliable.

Summary Of The Invention

The present invention aims at overcoming the disadvantages of conventional systems relative to the presence of demodulation gaps in the response of the demodulator of a read/write terminal.

More specifically, the present invention aims at providing a novel control method that makes a read/write terminal insensitive to demodulation gaps of the data that it receives from a transponder having entered its field.

The present invention also aims at providing a novel terminal insensitive to demodulation gaps of the data that it receives from a transponder having entered its field.

The present invention also aims at providing a solution which requires no modification of the transponders and which is accordingly compatible with existing transponders.

To achieve these and other objects, the present invention provides a method for controlling an electromagnetic field generation terminal using a signal for exciting an oscillating circuit, provided with means for regulating the signal phase in the oscillating circuit, including comparing current values of variables linked to the current in the oscillating circuit and to the voltage thereacross with predetermined values, to detect the presence of a transponder in the electromagnetic field.

According to an embodiment of the present invention, said predetermined values are measured and stored during an off-load operation of the terminal, while no transponder is present in its field.

According to an embodiment of the present invention, said presence detection is implemented when a demodulator included by the terminal detects no signal transmitted by the transponder.

According to an embodiment of the present invention, the method includes, in case of the detected presence of a transponder, deactivating the phase regulation, and forcing the imaginary part of the impedance of the oscillating circuit of the terminal to a predetermined value.

According to an embodiment of the present invention, the forcing of said imaginary part is performed by forcing the value of a variable capacitive element of the oscillating circuit.

According to an embodiment of the present invention, applied to a terminal provided with an amplitude demodulator, the predetermined value of forcing of said imaginary part corresponds to an off-load operation of the terminal.

According to an embodiment of the present invention, applied to a terminal provided with a phase demodulator, the predetermined value of forcing of said imaginary part is a function of the position of this imaginary part with respect to a limiting value corresponding to an off-load operation of the terminal.

According to an embodiment of the present invention, the method includes, in case of the detected presence of a transponder and in case of no data detection by an active demodulator among an amplitude demodulator and a phase demodulator included by the terminal, selecting the other demodulator to detect the data.

The present invention also provides an electromagnetic field generation terminal adapted to cooperating with at least one transponder when said transponder enters this field, and including means for implementing the method of the present invention.

The foregoing objects, features and advantages of the present invention, will be discussed in detail in the following non-limiting description of specific embodiments in connection with the accompanying drawings.

Brief Description Of The Drawings

Fig. 1 very schematically shows a conventional example of an electromagnetic transponder system;

Fig. 2 shows, in the form of a simplified flowchart, an embodiment of the method for validating the presence of a transponder according to the present invention;

Fig. 3A partially and schematically shows an embodiment of an amplitude demodulation read/write terminal according to the present invention;

Fig. 3B partially and schematically shows an embodiment of a phase demodulation read/write terminal according to the present invention;

Fig. 4A illustrates, in the form of a flowchart, a mode of implementation of the validation method of the present invention for an amplitude demodulation;

Fig. 4B illustrates, in the form of a flowchart, a mode of implementation of the validation method of the present invention for a phase demodulation;

Fig. 5A shows examples of the shape of the amplitude of the signal to be demodulated available at the input of the amplitude demodulator of a read/write terminal according to the capacitance of the oscillating circuit of a transponder in the field of this terminal;

Fig. 5B shows examples of the shape of the amplitude of the phase of the signal to be demodulated available at the input of the phase demodulator of a read/write terminal according to the capacitance of the oscillating circuit of a transponder having entered the field of this terminal; and

Fig. 6 very schematically shows an embodiment of a read/write terminal according to an alternative of the present invention.

Detailed Description

The same elements have been referred to with the same references in the different drawings. For clarity, only those elements of a terminal and of a transponder and only those steps of the information exchange process which are necessary to the understanding of the present invention have been illustrated in the drawings and will be described hereafter. In particular, the details constitutive of the modulators and demodulators have not been detailed and are within the abilities of those skilled in the art based on the functional indications given hereafter. Further, the present invention will be discussed in relation with transponders using a so-called "resistive" back-modulation to vary the load that they form on the terminal's

oscillating circuit (the capacitances of the oscillating circuits of the transponders being fixed), but it should be noted that the present invention more generally applies to any type of back-modulation, for example to a so-called "capacitive" back-modulation.

A feature of the present invention is to provide a direct determination of the presence of a transponder in the field of a read/write terminal, that is, without it being necessary to interpret demodulated data transmission signals coming from the transponder. More specifically, the present invention provides, in case of an absence of a demodulated signal usable by the terminal, validating the absence of a transponder in the field thereof by another determination independent from the existence of a data transmission.

Another feature of the present invention is to provide, in case of an incoherence between the result of the demodulator and of the direct determination, a corrective action enabling the terminal's demodulator to correctly interpret the received data. This corrective action is preferentially performed on the terminal's oscillating circuit and, preferably, on the capacitive element of this circuit.

The determination of the presence or the absence of a transponder in the terminal's field is performed, according to the present invention, by a measurement of the current in the terminal's oscillating circuit and of the voltage across its capacitive element (or of variables directly linked to the current and to the voltage), and by comparing the obtained current values with previously-stored values. The latter preferably correspond to values measured in a learning phase where the reader is in a specific configuration.

Afterwards, the possible corrective action may call on different calculations and comparisons, especially according to the type of demodulation (phase or amplitude) used by the terminal.

Fig. 2 is a simplified flowchart of a mode of implementation of a sequence of validation of the presence of a transponder in the terminal's field, applied to the stand-by state of a read/write terminal.

As soon as it is powered on and in operation, a transponder read/write terminal begins (block 20, ST), after a starting, set and test phase, a stand-by procedure during which it waits for a communication with a transponder to be established. This procedure includes periodically sending (block 21) a request sequence (REQ) to the possible transponder(s) present in the terminal's field. After each sending of an interrogation request 21, the reader

monitors (block 22) the reception, by its demodulator, of an acknowledgement message (ACK) coming from a transponder having entered its field.

In a conventional method (not shown), in the absence of an acknowledgement, the reader loops on the sending of a request 21. When its receives an acknowledgement ACK, it switches to a mode of checking whether the transponder really is a transponder intended therefor, as well as to a possible anti-collision mode (block 23, INIT/COM) to individualize several transponders that may be present in the field. Indeed, as a response to an interrogation request by a terminal, if several transponders are present in the field thereof, they may respond at the same time or with a sufficiently low time interval to make the result of the demodulation by the reader unexploitable. Said reader must then either select a transponder with which it wishes to communicate, or assign different channels to the different transponders.

A communication only starts when the initialization and anti-collision process illustrated in Fig. 2 by block 23 is over. As soon as a given transponder has been properly identified, it is placed in a state where it no longer acknowledges interrogation requests to avoid polluting the detection of the other possible transponders.

An initialization and anti-collision process of the type briefly described hereabove is known. Illustrations of conventional methods are for example to be found in French patent applications no. 2,760,280 and 2,773,627, which are hereby incorporated by reference.

Be it during stand-by procedures or during a communication, the terminal exploits the results provided by its demodulator.

According to the present invention, each time the reader expects to obtain a result from its demodulator and this result is negative (block 22), a validation procedure of the present invention (block 24, VALID) is implemented.

If the implementation of the method of the present invention validates the absence of a transponder in the terminal's field, the conventional sending of an interrogation request (link 25) is resumed. However, if the checking performed by the present invention invalidates the demodulator result and indicates that a transponder must be present in the terminal's field, a corrective action is performed on its oscillating circuit before carrying on the communication initialization (link 26).

To get rid of the problem of tolerance and drift of the transponders' oscillating circuit components, the values of these elements being further likely to vary from one transponder to

another, it is provided according to the present invention to regulate the phase of the terminal's oscillating circuit with respect to a reference value. According to the present invention, this phase regulation is performed by means of a loop having a response time chosen so that the loop is sufficiently slow to avoid disturbing the possible back-modulation from the transponder and sufficiently fast as compared to the passing speed of a transponder in the terminal's field. This can be called a static regulation with respect to the modulation frequencies (for example, the 13.56-MHz remote supply carrier frequency and the 847.5-kHz back-modulation frequency used in the data transmission from the transponder to the terminal).

Such a phase control of the terminal's oscillating circuit can be implemented by using known means such as those described, for example, in above-mentioned European patent application no. 0,857,981. The adaptation of the system provided by this document to implement the present invention, or of another known phase control system, is within the abilities of those skilled in the art based on the functional indications given in the present description.

Due to the use of a phase regulation loop, current and voltage measurements in the terminal's oscillating circuit can now be exploited to deduce therefrom, according to the present invention, an information relative to the presence of one or several transponders in the field.

The current, designated by I, in the terminal's series oscillating circuit (for example, measured by an intensity transformer) is linked to the so-called generator voltage (Vg), exciting the oscillating circuit and to the apparent impedance Z1app of the oscillating circuit by the following relation:

$$Z1_{app} = \frac{Vg}{I} \qquad (1)$$

Now, considering that the series inductance and resistance of the terminal's oscillating circuit have fixed and immutable values, at least for a given terminal, the excitation voltage of the oscillating circuit is proportional by a constant coefficient to the voltage (VC1) across the capacitive element of the terminal. Accordingly, evaluating the apparent impedance of the terminal's oscillating circuit amounts to evaluating the ratio between the voltage across the capacitive element and the current in the oscillating circuit.

The evaluation of the presence of a transponder performed by the present invention exclusively uses the current information in the terminal's oscillating circuit and the voltage information thereacross, more specifically across its capacitive element (or information directly linked, by invariable and determined coefficients, to these variables).

According to the present invention, the so-called "off-load" values of the current and of the voltage are used when no transponder is present in the terminal's field. These electric magnitudes are easily measurable on the read/write terminal side, for example, in a learning phase, for example following the implantation of the terminal in its application site.

Afterwards, by evaluating the current ratio (or a linked information) between the voltage across the capacitive element and the current in the oscillating circuit, the presence of a transponder in the field can be deduced.

Two embodiments of the present invention corresponding to two corrective actions to be performed according to the type of demodulator of the read/write terminal will be described hereafter. A first embodiment applied to an amplitude demodulation by the terminal will be described in relation with Figs. 3A, 4A, and 5A.

Fig. 3A schematically shows, in a simplified manner, a first embodiment of a read/write terminal according to the present invention, equipped with a phase regulation loop of the oscillating circuit and with an amplitude demodulator.

Conventionally, terminal 30 includes an oscillating circuit formed of an inductance or antenna L1, in series with a capacitive element 31 and a resistive element R1, between an output terminal 32 of an amplifier or antenna coupler 33 and a terminal 34 at a reference potential (generally, the ground). An element 35 for measuring the current in the oscillating circuit is interposed, for example, between capacitive element 31 and ground 34. Measurement element 35 is especially used to provide the information about the current (I) intended for the data exploitation means on the terminal side formed, for example, of a microprocessor (not shown). Amplifier 33 receives a high-frequency transmission signal E, coming from a modulator 36 (MOD1) which receives a reference frequency (signal OSC), for example, from a quartz oscillator (not shown). Modulator 36 receives, if necessary, a signal Tx of data to be transmitted and, in the absence of any data transmission from the terminal, provides the high-frequency carrier (for example at 13.56 MHz) adapted to remotely supplying a transponder. Capacitive element 31 is a variable-capacitance element controllable by a signal CTRL.

A phase regulation of the current in antenna L1 is performed with respect to a reference signal. This regulation is a regulation of the high-frequency signal, that is, of the carrier signal corresponding to signal E in the absence of data to be transmitted. This regulation is performed by varying the capacitance of the oscillating circuit of terminal 30 to maintain the current in the antenna in a constant phase relation with the reference signal which corresponds, for example, to signal OSC provided by the modulator's oscillator. However, the regulation is sufficiently slow to only take into account the static phase variations with respect to the back-modulation carrier. Signal CTRL originates from a circuit 37 (COMP) having the function of detecting the phase interval with respect to the reference signal and accordingly modifying the capacitance of element 31. In the present example, the phase measurement is performed from a measurement of current I in the circuit by means of current transformer 35 mounted in series with element 31. This transformer generally is formed of a primary winding 35' between element 31 and the ground, and of a secondary winding 35", a first terminal of which is directly connected to ground 34 and a second terminal of which provides a signal MES1 depending on current I, sent to comparator 37 which accordingly controls capacitive element 31 by means of signal CTRL.

According to the present invention, signal MES1 is also sent, as previously indicated, to the microprocessor or the like to implement the validation method of the present invention. A second measurement signal MES2, providing an information relative to voltage VC1 across capacitive element 31, is also sent to the microprocessor. This signal is sampled, for example, between inductance L1 and element 31.

In the embodiment illustrated in Fig. 3A, terminal 30 includes an amplitude demodulator 38 (DEMODA) receiving as an input, for example, voltage VC1 (or an image of the current) across capacitive element 31 (more specifically across the series association of capacitive element 31 and of current sensor 35) and providing as an output a signal Rx giving back a possible back-modulation of data received from a transponder to the rest of the terminal's electronic circuits, not shown.

Fig. 4A is a flowchart of an embodiment of the validation method (block 24, Fig. 2) of the present invention, applied to an amplitude demodulation.

As previously indicated, current I and voltage VC1 are first measured (block 40) in the oscillating circuit. Then, the ratio of voltage VC1 on current I is compared (block 41) to the same values, measured off-load (VC1off-load and Ioff-load) in a learning phase. If the

two ratios are identical, this means that no transponder is present in the terminal's field and the validation process provides this information (link 25). However, if the two ratios are different, this means that the demodulator is in a demodulation gap even though a transponder is present in the terminal's field.

Indeed, imaginary part X1app of apparent impedance Z1app of the terminal's oscillating circuit can be expressed as:

$$X1app = X1 - a2 \,.\, X2, \qquad (2)$$

where X1 represents the imaginary part of the impedance of the terminal's oscillating circuit, that is:

$$X1 = L1 \cdot \omega - \frac{1}{C1 \cdot \omega}, \qquad (3)$$

where X2 represents the imaginary part of the transponder's oscillating circuit, that is:

$$X2 = L2 \cdot \omega - \frac{1}{C2 \cdot \omega}, \qquad (4)$$

and with:

$$a^2 = \frac{k^2 \cdot \omega^2 \cdot L1 \cdot L2}{X2^2 + R2^2}, \qquad (5)$$

where ω represents the pulse and where R2 represents the load formed by the transponder's oscillating circuits on its own oscillating circuit, modeled by a resistor in parallel with inductance L2 and capacitor C2. In other words, resistor R2 represents the equivalent resistance of all the circuits (microprocessors, back-modulation means, etc.) of the transponder, added in parallel on capacitor C2 and inductance L2.

Due to the phase regulation, imaginary part X1app is null. Accordingly:

$$X1 = a2.X2. \qquad (6)$$

Based on these relations, the difference between the current and off-load values can be expressed as follows:

$$X1 - X1off\text{-}load = a2 \,.\, X2 - aoff\text{-}load2 \,.\, X2. \qquad (7)$$

Now, coefficient aoff-load is null since the off-load coupling is also null. Further, voltage VC1 across element 31 (neglecting the influence of intensity transformer 35) can be written as I/ωC1. As a result, formula (7) hereabove can be written as:

$$a^2X2 = \frac{VC1_{off-load}}{I_{off-load}} - \frac{VC1}{I}. \tag{8}$$

If above expression 8 is different from zero, this not only means that a transponder is present in the terminal's field, but also that, for this transponder, variable X2 is different from 0, that is, its oscillating circuit is out of tune, even slightly. This is perfectly coherent with the fact that the transponder transmits data to the terminal, that is, it modifies the load that it forms on the terminal's oscillating circuit.

In other words, it can be considered that the above formula annuls in two cases only. The first case corresponds to the case where no transponder is present in the terminal's field. The second case is that where capacitor C2 of the transponder's oscillating circuit is perfectly tuned on the remote supply carrier. In this case, X2 = 0.

In practice, technological dispersions and operating drifts of the transponder result in variations by more of less 10% of the capacitance of capacitor C2 with respect to a tuning value $C2_{tun}$. Further, nothing can generally be done on the transponder to correct these variations. This is in particular why the phase regulation loop enables optimizing the remote supply of the transponder by compensating for these possible drifts by modifying the tuning on the read/write terminal side.

The correction performed according to the present invention to come out of a demodulation gap includes, preferably, forcing the value of capacitance C1 of element 31 on a predetermined value in the learning phase. This choice is linked to the fact that the phase regulation is preferably performed by modifying the capacitance of the oscillating circuit. Accordingly, a variable capacitive element, the value of which can be adjusted, is provided, either to statically control the phase in the oscillating circuit, or to force the value of the capacitive element to shift the circuit tuning when in the presence of a demodulation gap.

The forcing of the value of capacitance C1 is performed, for example, by means of a signal COM issued by the processor (not shown) to a circuit 39 for selecting the control set point of element 31 between signal CTRL provided by circuit 37 and the forcing value. The practical implementation of this function is within the abilities of those skilled in the art. It may for example be provided that signal COM carrying the predetermined set point of capacitance C1 always holds the priority with respect to signal CTRL carrying the controlled set point, or an additional control signal (not shown) may be provided to select one of the two

inputs of circuit 39. As an alternative, the phase regulator may be modified to be able to impose a different set point value to it, enabling the forced value of capacitance C1 to be provided by signal CTRL.

It should be noted that by forcing the value of the capacitance, the phase in the oscillating is then no longer regulated. However, this correction of the present invention only intervenes in very specific cases where the demodulator is "blind". The regulation value of the capacitance is, of course, recovered as soon as this situation disappears, for example, as soon as the communication with the involved transponder ends.

In the embodiment of Figs. 3A, 4A, and 5A, capacitance C1 of element 31 of the oscillating circuit is forced (block 42) to a value C1f equal to the value C1off-load that it has off-load. This value of the off-load capacitance can easily be stored in the learning phase where the off-load current and voltage have been measured. The initialization process (Fig. 2) carries on (link 26) based on this new capacitance value.

Fig. 5A illustrates the first embodiment of the method of the present invention by showing three examples of variation amplitudes dI of current I, available for the amplitude demodulator according to capacitance C2 of the transponder present in the terminal's field. In other words, this illustrates the signal available to exploit a back-modulation coming from a transponder by means of the amplitude demodulator.

Variation dI corresponds, as a first approximation, to voltage variation dV across element 31, and represents the signal to be detected by amplitude demodulator 38. This is thus a "dynamic" variation (at the rate of the back-modulation remote carrier, for example, 847.5 kHz).

A first curve 50 plotted in full line corresponds to the ideal case where the imaginary part of impedance X1 (formula 3) of the terminal's oscillating circuit is null. This means that the terminal's oscillating circuit is perfectly tuned, including in its dynamic operation. This case is ideal since, given that the reader is provided with a phase loop, which is static with respect to the variations generated by the back-modulation (for example at 847.5 kHz), apparent value X1app is statically null (formula 2). It will be reminded that the essential aim of the static phase loop is to optimize the tuning according to the transponder's load to obtain an optimal remote supply range thereof. Shape 50 forms a sort of bell centered on value $C2_{tun}$ of the capacitance of a transponder perfectly tuned on the remote supply carrier.

With respect to this ideal case, two types of curves can be defined, respectively 51 in stripe-dot lines and 52 in dotted lines corresponding to two real cases where imaginary part X1 of the terminal's oscillating circuit is respectively positive or negative. The case where imaginary part X1 is positive means that the value of capacitance C1 of element 31 is greater than value C1off-load. Conversely, the case where imaginary part X1 is negative corresponds to a value of C1 smaller than C1off-load. In each of curves 51 and 52, points, respectively 53 and 54, appear in which the variation of current dI is null. These points correspond to demodulation gaps. It should be noted that curve 50 corresponding to the ideal case also exhibits two zero crossings 55 and 56, that is, two demodulation gaps. However, points 55 and 56 correspond, in practice, to values of capacitance C2 coming out of the tolerance and drift ranges. Gaps 55 and 56 surround points 53 and 54.

The implementation of the correction provided by the present invention corresponds to displacing the operating point of the reader to reach the ideal curve (shape 50). This action is symbolized by a double arrow 57 at the level of point 53 taken as an example. When a demodulation gap is identified, the value of capacitance C1 is forced to its off-load value. The terminal is then pulled out of the demodulation gap, and its demodulator then has enough signal amplitude to read the message sent by the transponder.

According to a specific embodiment, where variable-capacitance capacitive element 31 is formed of a diode or of a transistor, the junction capacitance of which is varied by modifying the voltage applied across its terminals, it can be considered that this control voltage corresponds to voltage VC1. In this case, it is possible to only store, in a learning phase, the value of the off-load capacitance as well as the off-load current. Then, as soon as a demodulation gap is detected, element C1 is biased to a value VC1off-load that is calculated by the following formula:

$$VC1_{off-load} = \frac{I_{off-load}}{\omega \cdot C1_{off-load}} . \qquad (9)$$

A second embodiment of the present invention applied to a phase demodulation by the terminal will be described hereafter in relation with Figs. 3B, 4B, and 5B, which should be compared with Figs. 3A, 4A, and 5A just described.

Fig. 3B shows an embodiment of a terminal 30 according to the present invention applied to a phase demodulation by said terminal. The difference between the terminal of Fig.

3B and that of Fig. 3A is mainly linked to the demodulator used. In the case of Fig. 3B, a phase demodulator (DEMODP) provides demodulated data signal Rx based on an evaluation of the phase shift at the rate of the back-modulation transmitted by a transponder. According to a preferred embodiment such as illustrated in Fig. 3B, comparator 37 of the phase regulation loop uses the same phase detector as that which is used to demodulate the signal coming from the transponder. Accordingly, signal Rx is provided by comparator 37. It will however be reminded that the interpretation of the detection result is different. The demodulator takes account of the dynamic variations (at the sub-carrier frequency) while the phase regulator takes static variations into account. As an alternative, two distinct phase detectors may of course be used. The rest of terminal 30 is similar to the structure discussed in relation with Fig. 3A applied to the amplitude demodulation.

Fig. 4B illustrates, by a flowchart, the correction applied according to the present invention to the value of the capacitive element of the terminal in the presence of a phase demodulation gap. Blocks 40 and 41 are similar to those discussed in relation with Fig. 4A. However, in the case of a phase demodulation, forcing the value of capacitance C1 on its off-load value would amount to forcing the tuning of the terminal's oscillating circuit on the carrier frequency. Now, it is then risked to come closer to the demodulation gap centered on the perfect tuning of the oscillating circuits of the terminal and of the transponder.

Fig. 5B shows three examples of shape of the variation dφ of the phase in the terminal's oscillating circuit according to the value taken by capacitance C2 of the transponder's oscillating circuit. Fig. 5B is to be compared with Fig. 5A applied to the amplitude modulation.

A first curve 60 plotted in full line corresponds to the ideal case where the imaginary part of impedance X1 (formula 3) of the terminal's oscillating circuit is null. As previously, this corresponds to the ideal case of a perfect tuning of the terminal.

Shape 60 grows hyperbolically, symmetrically, on either side of a minimum 65 at value $C2_{tun}$ of the capacitance of a transponder perfectly tuned on the remote supply carrier and which, in phase demodulation, corresponds to a demodulation gap.

With respect to this ideal case, two types of curves, respectively 61 in stripe-dot lines and 62 in dotted lines corresponding to two real cases where the imaginary part of the terminal's oscillating circuit is respectively positive or negative. In each of these curves 61

and 62, points, respectively 63 and 64, are seen to appear in which phase variation $d\varphi$ is null. These points correspond to demodulation gaps and surround point 65. It should be noted that curves 61 and 62 exhibit, each, a second minimum, on the other side of point 65 with respect to their first respective minima 63 and 64. These second minima are however outside of the tolerance and drift ranges of the transponder components. Accordingly, they are considered to be impossible in practice. In the example shown, symmetrical positions of minima 63 and 64 with respect to minimum 65 have been considered. This shows that curves 61 and 62 intersect for a value of capacitance C2 which corresponds to tuning value $C2_{tun}$.

It should be noted that, unlike the amplitude demodulation, zero crossing 65 of curve 60 representing the ideal case corresponds to a value of capacitance C2 included in the tolerance and drift ranges.

Three demodulation gaps 63, 64, and 65 are thus likely to be present in the response of the phase demodulation. According to the present invention, since it is not desirable to pass on the ideal curve, the correction to be brought differs according to the demodulation gap that is desired to be avoided. Accordingly, when the testing of block 41 gives a negative response, it must still be determined what demodulation gap is involved. For this purpose, the present invention provides a new analysis of the behavior of the oscillating circuits of a terminal and of a transponder to determine, still based on values calculated in a learning phase and on a comparison with current values, the correction to be performed.

It should be reminded that, to avoid affecting the remote supply of the transponder, the correction must, if possible, introduce no static detuning of the terminal's oscillating circuit. Indeed, the beneficial effect of the phase regulation loop on the transponder's remote supply is desired to be preserved. To maintain the remote supply without intervening on the components of the transponder's oscillating circuit, the amplitude of imaginary part X1 of the impedance of the terminal's oscillating circuit must not be modified by the correction. This amounts to maintaining the module of imaginary part X1.

Based on the illustration of Fig. 5B, it is provided according to the present invention to pass onto the symmetrical curve with respect to point 65, that is, onto the curve representing the imaginary part of opposite sign but of same module. This effect is illustrated, in Fig. 5B, by an arrow 67 illustrating the coming out of gap 63 of curve 61 by shifting on curve 62.

Based on relation 3 indicated hereabove, this amounts to choosing, for capacitance C1, the following forcing value C1f:

$$C1_f = \frac{1}{\omega \cdot (\omega \cdot L1 + X1)} \qquad (10)$$

Now, the current value of X1 (before correction) is known, either because this value is available at the level of phase regulation circuit 37, or from the following formula:

$$X1 = \omega \cdot L1 - \frac{VC1}{I} \qquad (11)$$

In the example of Fig. 4B, it is provided to calculate (block 44) imaginary part X1 based on relation 11 hereabove. It should be noted that all the variables necessary to this calculation are known or measurable (block 40, Fig. 4B).

However, if minimum 63 is close to minimum 65, the correction provided hereabove is not sufficient since the amplitude of the useful signal will remain insufficient on the symmetrical curve. In this case, the present invention provides forcing a value of X1 of opposite sign and sufficiently large to move away from the "theoretical" or "ideal" tuning gap 65. This amounts to passing onto another curve not only having its minimum separated from the current minimum by point 65, but also having a different value of the apparent impedance. A decrease of the transponder's remote supply must thus here be accepted. It is however attempted to make it a minimal decrease.

It can be shown that the demodulation gap tends towards value $C2_{tun}$ when imaginary part X1 tends towards a value X1 = k2.ω.L1, with k ranging between 0 and kmax, where kmax represents the maximum coupling coefficient between the oscillating circuits of the terminal and of the transponder, that is, the coupling coefficient between these two circuits when their respective antennas L1 and L2 are in a relation of maximum closeness.

Since ω.L1 is an invariant, only the value of k has an influence on that of X1.

Further, since all the adaptations provided by the present invention are intended for being performed in real time and automatically, a forcing value C1f easily determinable by a calculation based on stored and measured values must be provided. To have a sufficient value of X1, the value of k can be forced to kmax to be in the same conditions as those of a transponder at the maximum coupling where it is known to be out of a demodulation gap.

Accordingly, it is provided to predetermine, in the learning phase, a limiting value X1lim of the imaginary part of the impedance of the terminal's oscillating circuit below which the module must not fall. This value is given by the following relation:

$$X1_{lim} = k_{max}^{2} \cdot \omega \cdot L1. \qquad (12)$$

Coefficient kmax is, approximately but sufficiently, known for a given family of transponders for which the considered terminal is intended. It generally ranges between approximately 0.1 and 0.4.

As illustrated in Fig. 4B, after having calculated the current imaginary part X1 of the impedance of the terminal's oscillating circuit, its module is compared (block 45) to the module of limiting value $X1_{lim}$.

If the current module is greater than or equal to the limiting module, it may be proceeded as indicated hereabove and the forcing value of relation 10 hereabove is applied (block 46).

If the current module is smaller than the limiting module, it is attempted to determine on which side of the off-load value it is to be found. The ratios of the measured and off-load voltage VC1 and current I are thus measured (block 47). This amounts to determining whether imaginary part X1 is positive or negative.

If the current ratio is greater than the off-load ratio, the following forcing value is applied (block 48):

$$C1_f = \frac{C1_{off-load}}{1 + k_{max}^{2}}. \qquad (13)$$

If the current ratio is smaller than the off-load ratio, the following forcing value is applied (block 49):

$$C1_f = \frac{C1_{off-load}}{1 - k_{max}^{2}}. \qquad (14)$$

Once the capacitance of element 31 has been forced, the initialization process (Fig. 2) proceeds (link 26) based on this new capacitance value.

By applying the example of generally acknowledged values where k_{max} ranges between 0.1 and 0.4, the application of relations 13 and 14 results in choosing, in the first case, a value $C1_f$ ranging between approximately 0.8 and 0.9 times value $C1_{off\text{-}load}$ and, in the second case, a value $C1_f$ ranging between approximately 1.1 and 1.2 times value $C1_{off\text{-}load}$.

It should be noted that dynamic phase shift dφ can be measured, either on current I or on voltage VC1 or the like. Accordingly, the present invention also applies to the case where means other than a current sensor are used to detect the phase shift. This depends on the type of phase demodulator used.

Fig. 6 schematically shows a third embodiment of the present invention applied to a read/write terminal 70 provided, for the demodulation of the signals coming from a back-modulation by a transponder, with both a phase demodulator (DEMODP) and an amplitude demodulator (DEMODA). The interpretation of the existence of a transponder in the terminal's field is then used, not to modify the capacitance of the variable element of the terminal's oscillating circuit, but to select the demodulator to be used to extract signal Rx. Indeed, as appears from the above discussion of Figs. 5A and 5B, the demodulation gaps do not have the same positions (in value of capacitance C2) according to whether the terminal demodulates in amplitude or in phase. Further, in the presence of an amplitude demodulation gap (respectively a phase demodulation gap), it is certain that the demodulator of opposite type is not "blind" since the change of demodulator does not modify imaginary part X1app of the apparent impedance. For example, based on Figs. 5A and 5B, to change demodulators when in a gap, for example, 53 or 54, amounts to placing oneself on curve 61, respectively 62, for a same capacitance value C2.

Terminal 70 includes the same elements as those common to terminals 30 of Figs. 3A and 3B except for circuit 39. It further includes an amplitude demodulator 38 connected as in Fig. 3A and a phase demodulator, preferably similar to that of Fig. 3B. A selection circuit 71 receives the respective outputs 72 and 73 of the amplitude and phase demodulators and provides signal Rx to the processor (not shown). Circuit 71 is controlled by a two-state signal COM, coming from the processor and obtained, preferably, in a way similar to that of the above-described embodiments. A priority demodulator, that is, which is selected in the absence of a demodulation gap, is determined. A simplified validation process is then implemented, which consists, as compared to the flowcharts of Figs. 4A and 4B, of detecting the presence of a demodulation gap. If there is one, signal COM switches to cause the selection of the output of the other demodulator. As an alternative, the selection circuit may be placed upstream of the demodulators.

An advantage of the present invention is that by means of a determination of easily measurable electric variables, the reliability of the operation of a read/write terminal of electromagnetic transponders is considerably improved.

Another advantage of the present invention is that the only intervention is on the read/write terminal side. Accordingly, the operation of the transponder present in the terminal's field is not modified and the present invention can be implemented with existing conventional transponders.

Another advantage of the present invention is that by choosing to intervene on the setting variable of the static phase regulation loop, structural modifications of the terminal are minimized.

Another advantage of the present invention is that it makes the operation of the transponder system insensitive to demodulation gaps.

Another advantage of the present invention is that the implemented correction does not adversely affect the transponder remote supply.

Another advantage of the present invention is that it requires no adaptation according to the demodulator sensitivity. It can even be considered that it automatically adapts to a variation of the demodulation gap. Indeed, since the correction performed by the present invention is implemented based on the result of the demodulation, it is independent from the demodulator's detection threshold.

Of course, the present invention is likely to have various alterations, modifications, and improvements which will readily occur to those skilled in the art. In particular, the practical implementation of the validation process of the present invention by means of the conventional components of a read/write terminal is within the abilities of those skilled in the art based on the functional indications given hereabove and on the considered application.

Further, although reference has been made in the foregoing description to the presence of a transponder with which the terminal is to communicate, the present invention also applies to the case where several transponders must communicate with a same terminal. In a simplified way, it can then be provided to force the value of capacitance C1 as soon as one of the transponders has been identified as posing a demodulation gap problem. It is then considered that the attenuation of the useful signal that may result therefrom for the other transponders is bearable. However, in a preferred embodiment, account is taken of the fact that the value forced for a transponder has a risk, even slight, of placing another transponder

in a demodulation gap. It is then provided to individualize the values of the capacitances of element 31 of the terminal to the different transponders. This is possible when the communications of several transponders with the same terminal are separated in time channels. Then, either the values of capacitance C1 can be stored upon detection of the transponders and one of these values can be imposed upon each channel switching (and thus transponder switching), or the validation steps (block 24, Fig. 2) can be provided upon each beginning of transmission of a data sequence from a transponder to the terminal. An advantage of this last solution is that it then takes into account the possible motions of a transponder during communication. It should be noted that it is possible to implement this last solution in the case of a single transponder to take account of this last advantage.

Moreover, in the foregoing description, it has been considered that the value of capacitance C2 is fixed, that is, that the back-modulation is performed by varying equivalent resistance R2. However, the present invention transposes to the case of a "capacitive" back-modulation that modifies the value of capacitance C2 at the sub-carrier rate. In this case, the demodulation gaps depend on resistance R2 and thus vary according to the consumption of the transponder circuits. The above-discussed detection principle is not modified. The correction will simply be adapted on the terminal side.

Finally, although the determination based on the voltage across capacitive element 31 is a solution that is particularly simple to implement, account may be taken of an equivalent voltage sampled at other points, provided that it is linked to the voltage across the terminal's oscillating circuit and that it is responsive (dynamically) to the variations caused by the back-modulation of a transponder.

Such alterations, modifications, and improvements are intended to be part of this disclosure, and are intended to be within the spirit and the scope of the present invention. Accordingly, the foregoing description is by way of example only and is not intended to be limiting. The present invention is limited only as defined in the following claims and the equivalents thereto.

What is claimed is: